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# Guidelines for Reducing Porpoise Mortality in Tuna Purse Seining

James M. Coe, David B. Holts, and Richard W. Butler

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# Guidelines for Reducing Porpoise Mortality in Tuna Purse Seining

JAMES M. COE,[1] DAVID B. HOLTS,[2] and RICHARD W. BUTLER[3]

## ABSTRACT

**More than a decade has passed since the passage of the Marine Mammal Protection Act of 1972. During that time the U.S. tuna purse seine fleet reduced its incidental porpoise mortality rate more than 10-fold. This was made possible through the development of gear and techniques aimed at reducing the frequency of many low probability events that contribute to the kill.**

**Porpoise are killed by becoming entangled or entrapped in folds and canopies of the net and suffocating. The configuration of the net, both before and during the backdown release procedure, is a major determinant of the number of porpoise killed. Speedboats can be used to tow on the corkline to prevent net collapse and also to adjust the net configuration to reduce net canopies prior to backdown. Deepening a net can reduce the probability of porpoise being killed by prebackdown net collapse. The effects of environmental conditions and mechanical failures on net configuration can result in high porpoise mortality unless mitigated by skilled vessel maneuvers or prevented by the timely use of speedboats to adjust the net.**

**The backdown procedure is the only means to effectively release captured porpoise from a purse seine. It is also the time during the set when most of the mortality occurs. The use of small mesh safety panels and aprons in the backdown areas of nets reduces porpoise entanglement, and increases the probability of an effective release. The tie-down points on the net for preparing the backdown channel must be properly located in order to optimize porpoise release. A formula uses the stretched depth of the net to calculate one of these points, making it a simple matter to locate the other. Understanding the dynamics of the backdown procedure permits a thorough troubleshooting of performance, thus preventing the repetition of poorly executed backdowns and thereby reducing mortality.**

**Porpoise that cannot be released must be rescued by hand. A rescuer in a rigidly inflated raft can rescue porpoise effectively at any time during a net set. Hand rescue can make the difference between above average kill and zero kill sets. In all circumstances, the skill and motivation of the captain and his crew are the final determinants in the prevention of incidental porpoise mortality in tuna seining.**

## INTRODUCTION

The purse seining method of catching yellowfin tuna, *Thunnus albacares*, in association with schools of porpoise[4] in the eastern tropical Pacific has been described by Perrin (1969) and Peters (1979). The primary target species, in order of importance, are the spotted dolphin, *Stenella attenuata*, and the spinner dolphin, *S. longirostris*, with occasional net sets made on schools of the common dolphin, *Delphinus delphis*. Schools of these porpoise, ranging in size from 50 to several thousand, are herded with speedboats and encircled with a purse seine net that is from 900 to 1,400 m long and as much as 130 m deep. After the porpoise are encircled, the bottom of the net is pursed, entrapping the mammals and any tuna that are associated with the school.

The incidental mortality rate of these marine mammals was estimated to exceed 40/set[5] in 1972, the year the Marine Mammal Protection Act was passed (Table 1, Fig. 1). The U.S. tuna fleet, with assistance from both private and government fishery specialists, succeeded in reducing their kill rate to 4/set by 1980. During this period the development and utilization of new gear and procedures, coupled with increased operator skill, reduced the frequency of high kill sets (Table 1) and increased the number of zero-kill sets (Fig. 2). The technology leading to these results is in varied used in both the domestic and foreign tuna fleets.

Individual captains have repeatedly demonstrated that over 99.9% of all captured porpoise can be released unharmed when the gear and techniques described in this report are skillfully employed. In the absence of future innovations to reduce mortality, further improvements in fleet performance may only be gained by heightening the skill and motivation levels of the vessel operators and by improving the durability and reliability of vessel equipment. This is no easy task. Vessel operators must be constantly prepared to prevent, avoid, or remedy a collection of very low probability events, any one of which may result in porpoise being killed. They must attempt to minimize the negative affects of environmental conditions, equipment failures, and porpoise behavior on the outcome of each set. This diligence must be maintained in the face of the risk of losing part or all of the tuna catch

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[4]Porpoise, in this paper, is used as a general term referring collectively to all small cetaceans impacted by the fishery. While dolphin is the more scientifically correct term, porpoise continues to be the term used by fishermen and researchers alike. The three major species involved are the spotted, spinner, and common dolphins: *Stenella attenuata*, *S. longirostris*, and *Delphinus delphis*.

[5]Mortality or kill refers to porpoise mortality incidental to the catch of yellowfin tuna, *Thunnus albacares*. The "set" is defined as a single deployment of a purse seine net around an aggregation of porpoise and/or tuna. Tuna catches are expressed in short tons.

Table 1.—Summary statistics of porpoise sets from NMFS observer trips, 1971-80. Numbers in parentheses are sample sizes.

| Statistic | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 |
|---|---|---|---|---|---|---|---|---|---|---|
| Total no. porpoise sets | 51 | 273 | 705 | 993 | 948 | 754 | 3,408 | 1,811 | 2,036 | 1,007 |
| No. pure spotted porpoise sets | 23 | 117 | 302 | 425 | 361 | 255 | 1,093 | 931 | 1,015 | 587 |
| No. pure spinner porpoise sets | 0 | 0 | 17 | 15 | 11 | 9 | 14 | 8 | 7 | 6 |
| No. mixed spotted and spinner sets | 25 | 132 | 279 | 365 | 412 | 399 | 756 | 680 | 503 | 257 |
| No. common-dolphin sets | 2 | 23 | 105 | 142 | 96 | 55 | 10 | 4 | 7 | 1 |
| No. others and unidentified porpoise sets | 1 | 1 | 2 | 46 | 68 | 36 | 1,535 | 188 | 504 | 156 |
| Average tons of yellowfin/set | 18(48) | 20(272) | 14(705) | 11(993) | 13(948) | 13(754) | 12(3,408) | 11(1,811) | 11(2,035) | 10(1,006) |
| Average number of porpoise caught/set | 219(48) | 486(245) | 378(705) | 355(980) | 634(947) | 816(720) | 813(3,107) | 821(1,612) | 658(1,797) | 643(905) |
| Average porpoise school size/set[1] | 298(48) | 1,007(239) | 907(703) | 1,163(866) | 1,216(945) | 1,419(734) | 1,656(3,205) | 1,446(1,669) | 1,170(1,870) | 1,054(935) |
| Average porpoise kill/set | 70(48) | 43(272) | 19(705) | 12(993) | 16(947) | 14(754) | 3(3,408) | 4(1,809) | 3(2,034) | 4(1,006) |
| Average porpoise kill/ton of yellowfin | 3.8 | 2.2 | 1.3 | 1.1 | 1.3 | 1.1(754) | 0.2(3,408) | 0.4(1,809) | 0.2(2,033) | 0.3(1,006) |
| Percent porpoise killed of porpoise caught | 31.9 | 8.9 | 4.9 | 3.4 | 2.5 | 1.8(720) | 0.4(3,107) | 0.5(1,611) | 0.3(1,797) | 1.6(904) |
| Percent of school captured[1] | 73.5 | 48.3 | 41.7 | 30.5 | 52.2 | 57.4(719) | 49.6(2,984) | 57.5(1,540) | 58.3(1,730) | 63.1(885) |
| Percent of school killed[1] | 23.5 | 4.3 | 2.1 | 1.0 | 1.3 | 1.0(734) | 0.2(3,205) | 0.3(1,667) | 0.2(1,868) | 0.4(934) |
| Percent of sets catching yellowfin | 92(48) | 89(273) | 82(705) | 74(993) | 82(948) | 83.3(754) | 84.7(3,408) | 85.3(1,811) | 87.3(2,035) | 91.3(1,006) |
| Percent of sets catching porpoise | 100(48) | 91(273) | 86(705) | 83(993) | 91(947) | 91.4(720) | 95.5(3,107) | 97.4(1,612) | 97.2(1,797) | 99.3(905) |
| Percent of sets catching porpoise with 0 killed | 2(48) | 12(248) | 18(601) | 22(827) | 24(863) | 30.4(658) | 56.5(2,968) | 58.4(1,569) | 71.4(1,746) | 67.5(898) |

[1]Estimates generally have a low precision.

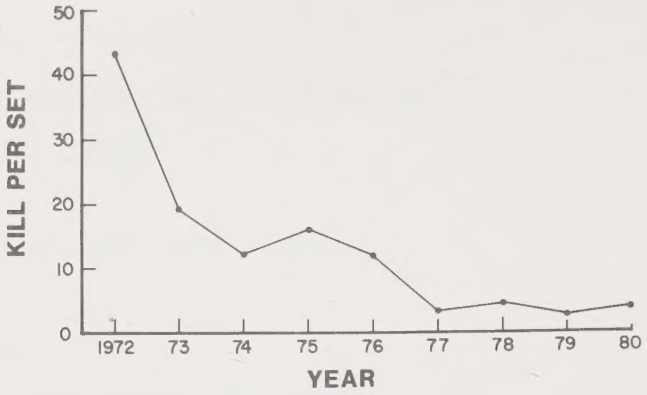


Figure 1.—Average porpoise kill per observed set.

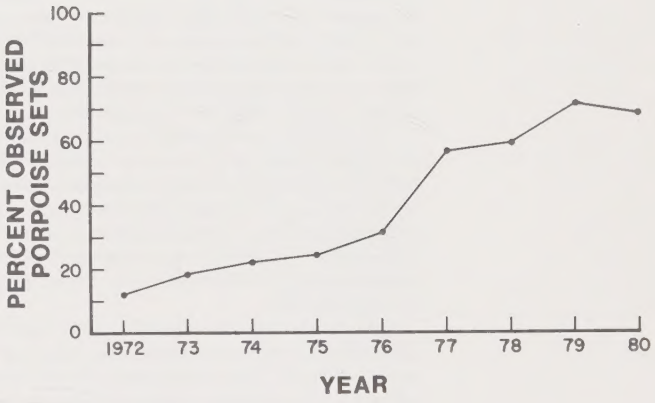


Figure 2.—Percent of observed porpoise sets with zero porpoise killed.

while attempting to release every captured porpoise. The annual kill quotas for the U.S. fleet are set at 20,500 animals/yr (NOAA 1980[6]) for 1981 through 1985. At this level, the performance of individual vessels can have a major impact on the length of the fishing season, justifying extreme diligence by vessel operators.

The intent of this paper is to bring together information relevant to the occurrence and prevention of porpoise mortality in tuna purse seining as a record of the present state of the art and as a baseline for future research and development. It should be noted that there are many events which may increase the probability of porpoise being killed for which no specific preventive or remedial measures exist. The most important of these are discussed.

Porpoise are killed when confined by the net in such a way that they are unable to rise to the surface to breathe. Aside from occasional shark attacks and encounters with vessel power equipment (speedboats, power block, net skiff, brailer, etc.), death by suffocation is the rule. Physically, the animals are either entangled individually in the meshes or are entrapped singly or in groups by folds or "canopies" of webbing. The probability that animals will become entangled or entrapped depends upon the configuration of the net, the number of porpoise and amount of tuna captured, their behavior, and the skill of the vessel operator. Table 2 shows the

[6]NOAA. 1980. Draft Environmental Impact Statement: Proposed regulations and conditions for the issuance of a general permit governing the taking of marine mammals associated with tuna purse seining operations. Department of Commerce, National Oceanic and Atmospheric Administration, NMFS, November 1980, 88 p.

Table 2.—Numbers of porpoise killed by general cause in sets with greater than 15 porpoise killed; NMFS observed trips 1977-80.

| Year | Number of sets (%) | Total kill (%) | Backdown canopies | | | | Prebackdown net collapse | Backdown channel collapse | Malfunction mortalities | All other causes | Unknown |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Bow | Stern | Other | Total | | | | | |
| 1977 | 135 (4.0) | 5,277 (51.6) | 749 | 1,539 | 774 | 3,062 | 440 | 346 | 329 | 339 | 780 |
| 1978 | 73 (4.6) | 4,932 (68.0) | 478 | 486 | 872 | 1,836 | 1,897 | 338 | 397 | 243 | 221 |
| 1979 | 54 (3.5) | 2,879 (47.1) | 960 | 173 | 43 | 1,176 | 284 | 326 | 84 | 925 | 84 |
| 1980 | 30 (2.9) | 2,647 (65.7) | 106 | 206 | 220 | 532 | 29 | 1,504 | 303 | 140 | 139 |
| Total | 292 (3.9) | 15,735 (67.0) | 2,293 | 2,404 | 1,909 | 6,606 | 2,650 | 2,514 | 1,113 | 1,647 | 1,224 |
| Percent of total kill | | 100 | 15 | 15 | 12 | 42 | 17 | 16 | 7 | 10 | 8 |

primary causes of kill for observed sets with 16 or more porpoise killed ("disaster sets") for 1977 through 1980. Note that the primary causes are related to net configuration (i.e., backdown canopies, prebackdown net collapse, backdown channel collapse, etc.). Most of the malfunction-related kill is also due to resultant net-configuration problems. An example of an "other" cause of mortality is when the dolphins are "sacked-up" in the net with the tuna and suffocated. The unknown causes of kill are usually unobserved but are probably related to the behavior of the captured porpoise, e.g., for no apparent reason some animals dive under the boat and become entrapped in the net when trying to return to the surface.

Prevention of incidental porpoise mortality involves three distinct activities during the set: 1) From the time of encirclement until its release, the porpoise school must be safely maintained within the net, 2) the school must be released from the net without allowing the tuna to escape and, 3) individual porpoise must be rescued whenever possible.

## PREVENTION OF PRERELEASE MORTALITY

The captain must safely maintain the captured porpoise in the net until he is able to release them using the backdown maneuver (Coe and Sousa 1972), normally a period of about 1 h.

Table 2 indicates that a less-than-optimum net configuration is a primary cause of porpoise mortality. Chief among the various configuration problems is prebackdown net collapse, which can be caused by strong currents, changes in wind direction and strength, major equipment malfunctions, failure of the captain to orient the set properly with the wind, or any combination of these. Regardless of the cause of prebackdown net collapse, the outcome is the same, i.e., a substantial portion of the captured porpoise school may be killed and the tuna may be lost as well. Realizing that the harvest of tuna will always involve occasional sets under adverse environmental conditions and that equipment malfunctions cannot always be prevented, the main technique for preventing prerelease mortality addresses the symptoms of net collapse rather than its causes.

### Towing with Speedboats to Prevent Net Collapse

Use of speedboats can prevent or delay net collapse during pursing and hauling operations (Everett et al. 1976[7]). Net collapse occurs when the surface area of the net is decreased, forcing the porpoise into contact with the webbing and preventing them from surfacing to breathe. The effectiveness of speedboats in preventing net collapse is totally dependent on acting before the net has collapsed around a school of porpoise. The captain conducting the fishing operations must understand that once a net is collapsed, speedboats will not be able to reopen it.

Four effective methods have been demonstrated for towing on the net; each adapted to a particular set of circumstances. The four methods (Fig. 3) are: 1) Towing directly on the corkline, 2) towing on the end of one bunchline, 3) towing on the middle of an open-ended bunchline and, 4) towing on the ends of two adjacent bunchlines (one reversible and one regular which together create a towing point).

Towing directly on the corkline is best used to clear small collapsed sections or small canopies in which the corkline is tight. This method (Method 1) is particularly useful for eliminating a partially collapsed backdown channel just prior to backdown. The best towing method when the corkline is not under tension is to tow on the bunchlines so the excess slack in the corkline is gathered together into bunches (Fig. 4). Here the speedboat is hooked-up to the ends of two adjacent bunchlines (Method 4), one regular and one reversible, which together create a single towing point specifically designed for this purpose. Since the net takes many different shapes while it is pursed and/or collapsed, it may not always be possible for the speedboat to pull on the towing points. In this case the fish captain may require the speedboat to

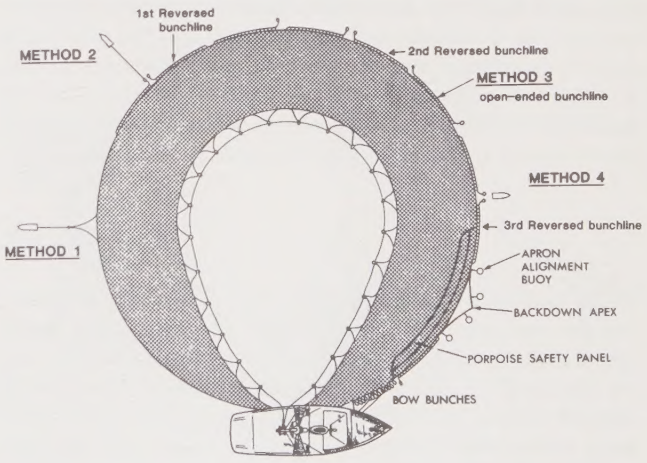


**Figure 3.—Purse seine towing points for holding net open using speedboats. The three reversed bunchlines should be strategically located around the perimeter of the net but should not interfere with the porpoise apron (Method 4). Speedboats may at times find it better to pull only one regular bunchline from its end (Method 2), or from its center if its open-ended (Method 3). Speedboats may also pull directly on the corkline (Method 1) to remove small net collapses and canopies.**

[7]Everett, J., J. E. Powers, R. McNeely, J. M. Coe, and R. Butler. 1976. The use of speedboats in reducing incidental porpoise mortality in tuna purse seining. Southwest Fisheries Center Admin. Rep. LJ-76-35, 29 p.

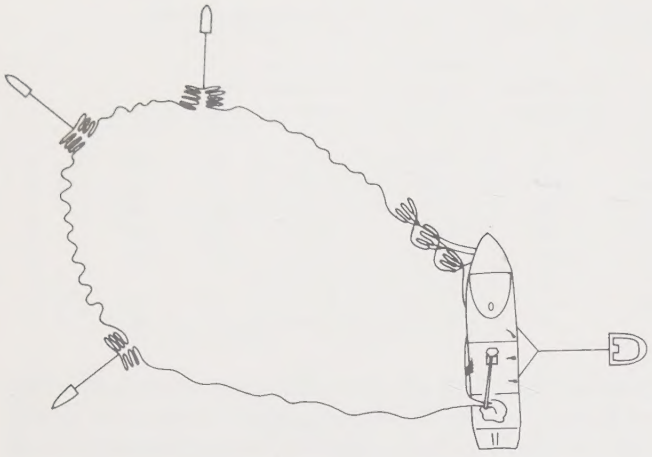

**Figure 4.—Idealized configuration of net under tow by speedboats.**

tow on the middle (Method 3) or the end of a single bunchline (Method 2). Whenever the corkline is slack, towing must be accomplished by towing on the bunchlines at some point which will allow the corkline to be gathered together.

Towing bridles are required on the stern of all speedboats for pulling (towing) on the net when the speedboat is engaged in the forward mode (Fig. 5). The stern towing bridle is made to hang loosely (but not so that it interferes with the propeller) and has a sliding ring for hooking-up with the towline. The towline should either be permanently attached to the sliding ring, or be made to hook-up to the ring easily with a snap hook. The opposite end of the towline should have a snap hook for quick attachment to the ends of the bunchlines or to the corkline.

Webbing shoaling near the surface may prevent a speedboat from towing with the stern towing bridle. In these circumstances the only alternative is to use the speedboat's bowline and tow in the reverse mode. This method is not nearly as efficient as towing with the stern towline, but it is useful under certain circumstances (such as small canopy removal).

Three towing points should be located on the corkline at approximately 1/4, 1/2, and 3/4 net. Each towing point is made of two adjacent bunchlines, one reversed and one normally oriented (Fig. 3). The length of these towing point bunchlines should be about 30-55 m (20-30 fathoms) for each line. These bunchlines should be positioned so that their use will not interfere with formation of the backdown channel. Use of a towing point located on the porpoise safety panel could cause major canopies during backdown resulting in entrapment instead of release.

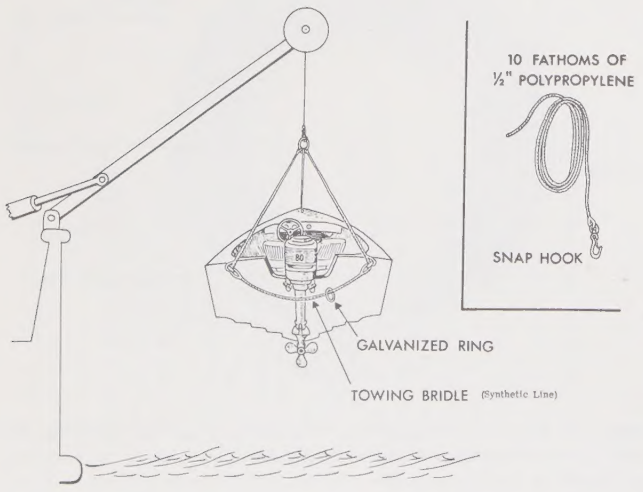


**Figure 5.—Rigging for speedboat towing bridle. Note that the galvanized ring is free to slide the entire length of the towing bridle.**

## Net Depth Effects

As soon as a net is set and pursing begins, the net starts collapsing (i.e., the enclosed surface area decreases). The degree of net collapse that occurs between encircling and releasing the porpoise determines, to a large extent, the probability of prebackdown mortality. The rate of collapse, among other things, is dependent on the depth of the net: The deeper the net, the greater surface area and volume during pursing and throughout backdown. Increased surface area allows the net to remain open longer and reduces the likelihood of porpoise being forced into contact with the webbing due to net collapse.

As part of an experiment conducted in 1979,[8] a 12-strip net was deepened to 14 strips and the increased surface area estimated (Fig. 6). The two-strip addition in depth gave rise to an 11.5% increase in the surface area when pursed and increased fishing depth by 17.2 m (9.4 fathoms). The deepened net could be pursed faster and had a larger backdown channel than the original.

Figure 7 shows a method of deepening the center section of a purse seine by two strips using six equal-length bales of webbing and a 4-mesh, 2-bar taper. This method may be applied to the addition of any even number of bales of equal length to give a two-strip increase in depth. If the bales are each 183 m (100 fathoms) long, the top of the tapered insert will be 220 m (120 fathoms) longer than the bottom side. For example, six 183 m bales, each 100 meshes deep, produce an insert 659 m (360

[8]Unpublished cruise reports: M/V *Cabrillo* May 19, to July 19, 1979 and August 18, to October 7, 1979. On file at the Southwest Fisheries Center, Oceanic Fisheries Resources Division, P.O. Box 271, La Jolla, CA 92038.

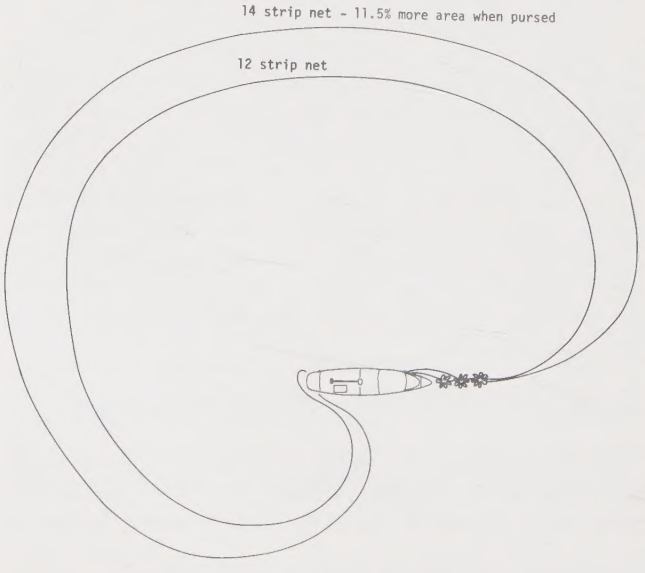


**Figure 6.—Deeper nets increase surface area. Actual measurements made during local and at-sea tuna boat charters have demonstrated an 11.5% increase in surface area when pursed by adding two strips to the center of a 12-strip net.**

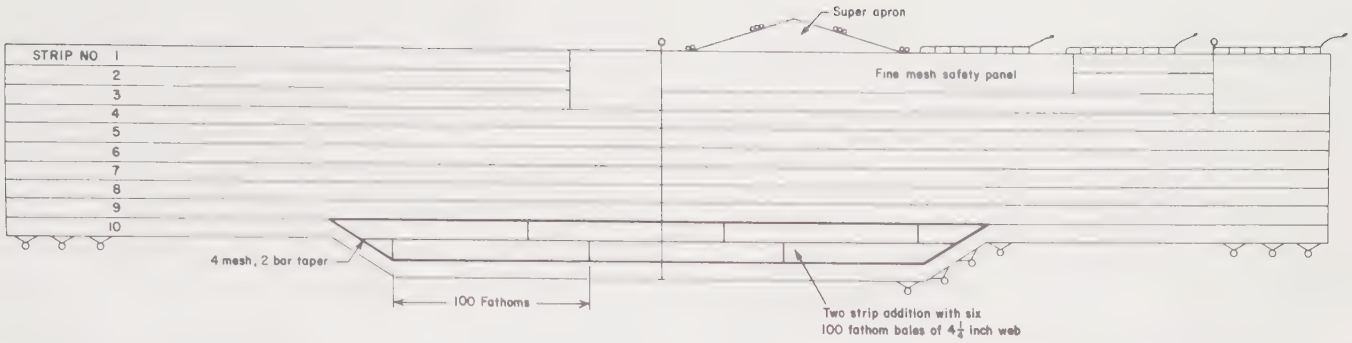


**Figure 7.—A two-strip addition in the center of a 10- or 12-strip net can be accomplished with 5, 8, or 10 bales of web, depending on the length of net. The addition is installed between the last strip and the strip above. When only six 100-fathom bales are used, the top edge of the addition will measure 360 fathoms while the shorter bottom edge measures 240 fathoms. Note: New tie-down points must be determined for backdown anytime the depth of the net is changed.**

fathoms) long on top, 439 m (240 fathoms) long on the bottom, with two tapered edges of 110 m (60 fathoms) each. If eight 183 m bales are used, the top will be 842 m (460 fathoms) long and the bottom will be 622 m (340 fathoms) long. Nets that are already tapered or are going to be deepened by more than two strips should be examined carefully to decide on the most suitable and economical deepening plan. When deepening a purse seine, it should be kept in mind that nets with a depth-to-length ratio higher than 1:7 may require a slowdown of pursing to avoid excessive strain on the webbing (Fridman 1969).

## The Mid-Net Zipper

It has long been suspected that unobserved porpoise mortality occurs in deep areas of the seine prior to backdown. Research divers have observed that the mid-net zipper may hold up a wall of webbing 10 m or more above the floor of the net. This wall, or "mid-net zipper ridge" forms during the pursing operation and persists until that part of the net is retrieved (Fig. 8). Captured porpoise ordinarily concentrate over the deepest area of the net. Consequently, when large numbers of porpoise and tuna are captured they may be forced to cross over the zipper ridge, increasing

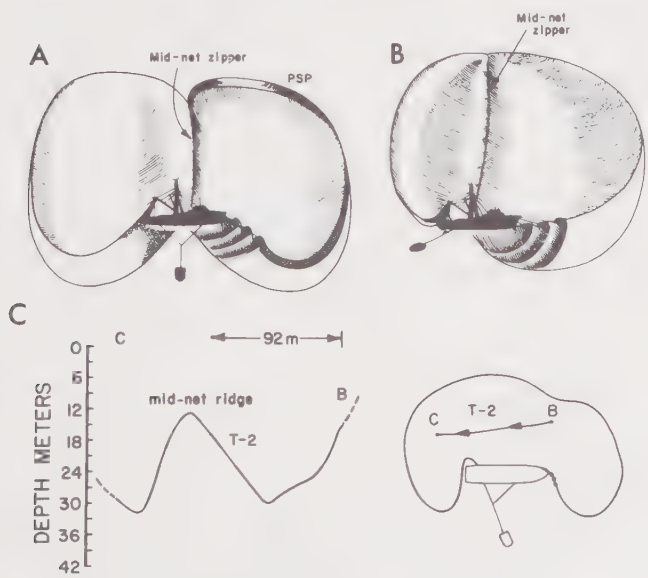


**Figure 8.—A. Mid-net zipper ridge when fully pursed. Note indentation of corkline opposite vessel. B. Zipper ridge with one-fourth net retrieved aboard vessel. C. Fathometer trace when fully pursed.**

probability of entanglement or entrapment. Divers have observed porpoise entangled in the overhanging wall of webbing and lesser folds associated with this area (Holts et al. 1979[9]) but, the extent of mortality attributable to the zipper ridge has not been determined.

The zipper ridge forms when the "stopper" webbing (a vertical strip of webbing of heavy construction designed to stop rips in the net) is prevented from extending down as far as the adjacent lighter web in the main body of the purse seine. Its formation most commonly results from improper installation of the heavier and stronger "stopper" webbing. Less common causes for the ridge include a short zipper line and incorrectly installed guide rings.

A close look at zipper installation techniques has shown a definite advantage for those seines in which the stopper was installed with an appropriate amount of hang-in slack. While other factors may contribute to restrict full extension of the stopper, one fairly simple adjustment can eliminate them. This adjustment is most easily made at dockside but can be done at sea. The 127 mm (5-in) mesh stopper must be rehung to the 108 mm (4¼-in) mesh with enough slack to permit full extension of the stopper. Here the existing 127 mm mesh stopper webbing is cut out of the seine and rehung, mesh-for-mesh, to the 108 mm mesh. This provides approximately 30% slack in the stopper webbing. An additional one to three meshes of stopper web should be "killed-in" to each strip of the 108 mm mesh. For example, about 4 m of additional slack are provided when only two 127 mm meshes are killed-in for each strip of a 14-strip net. This procedure will ensure a problem-free zipper line by providing for differential shrinkage rates between the 127 and 108 mm mesh, should it occur (Holts 1980).

## Downwind Sets

Occasionally, an operator will set the net downwind of the vessel, that is, with the wind blowing the vessel into the net. "Downwind sets" occur very infrequently but can result in a large portion of the captured porpoise being killed. These sets are highly susceptible to net collapse and tend to be more frequent with less experienced captains. Experienced captains will circle around the porpoise school and set when the wind is on the port bow (Fig. 9), insuring that the net circle will be upwind of the vessel, reducing the risk of net collapse.

[9]Holts, D. B., R. McLain, F. G. Alverson, and J. DeBeer. 1979. Summary of research results from the fifth cruise of the dedicated vessel. November 11 to December 9, 1978. Southwest Fisheries Center Admin. Rep. LF-79-20, 60 p.

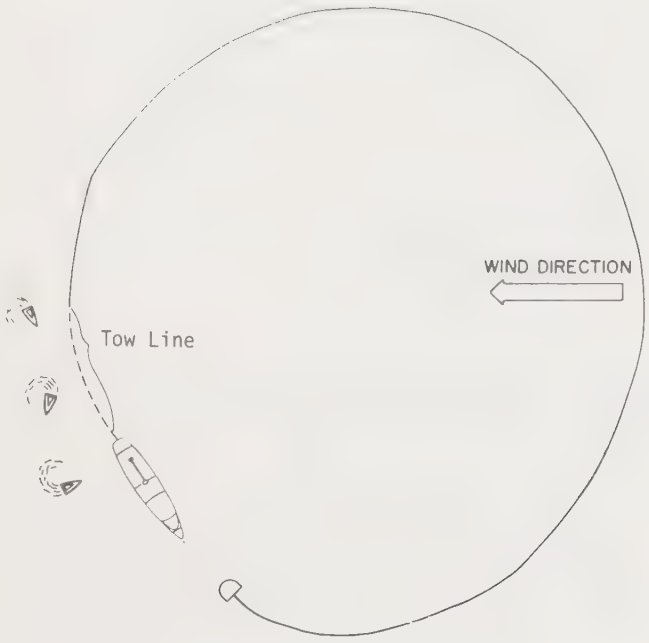


**Figure 9.—Always set after turning into the wind. This will keep the net upwind of the vessel.**

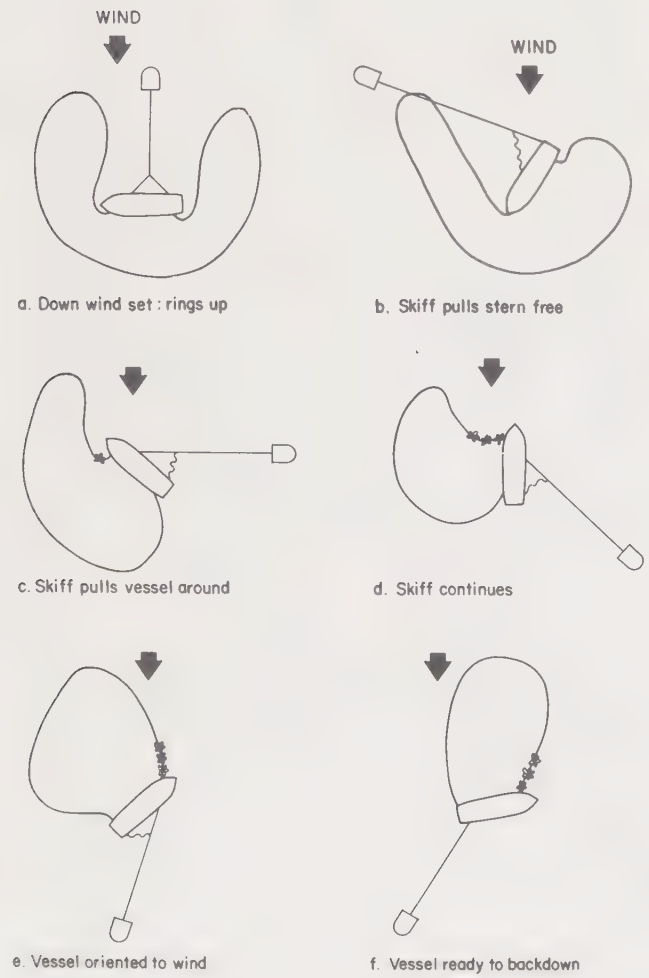
WIND
a. Down wind set : rings up
WIND
b. Skiff pulls stern free
c. Skiff pulls vessel around
d. Skiff continues
e. Vessel oriented to wind
f. Vessel ready to backdown

**Figure 10.—Procedure for turning vessel around after making a downwind set.**

If the net is accidently set downwind of the vessel, the captain must pay particular attention to the developing bow and stern bends in order to maintain near-equal surface areas in each (Fig. 10a). As soon as pursing is completed, the skiff should tow the seiner's stern out and clear of the stern bend in order to avoid possible entanglement on the propeller. As the stern bend is rolled on board (Fig. 10b, c, d), the skiff should begin towing the vessel around until the wind is on the port side. Using the skiff and bow-thruster to move the vessel around to the wind should provide a good net configuration before backdown (Fig. 10f). The biggest danger with these sets is to act too late or not at all.

## Using Speedboats to Move Porpoise Inside the Net

Speedboats have long been used to herd and concentrate porpoise in order to encircle them. This is effective because porpoise have a keen acoustical sense and tend to avoid the speedboats. Speedboats are also used during a set to influence the location of porpoise within the net. Circling just outside of the corkline

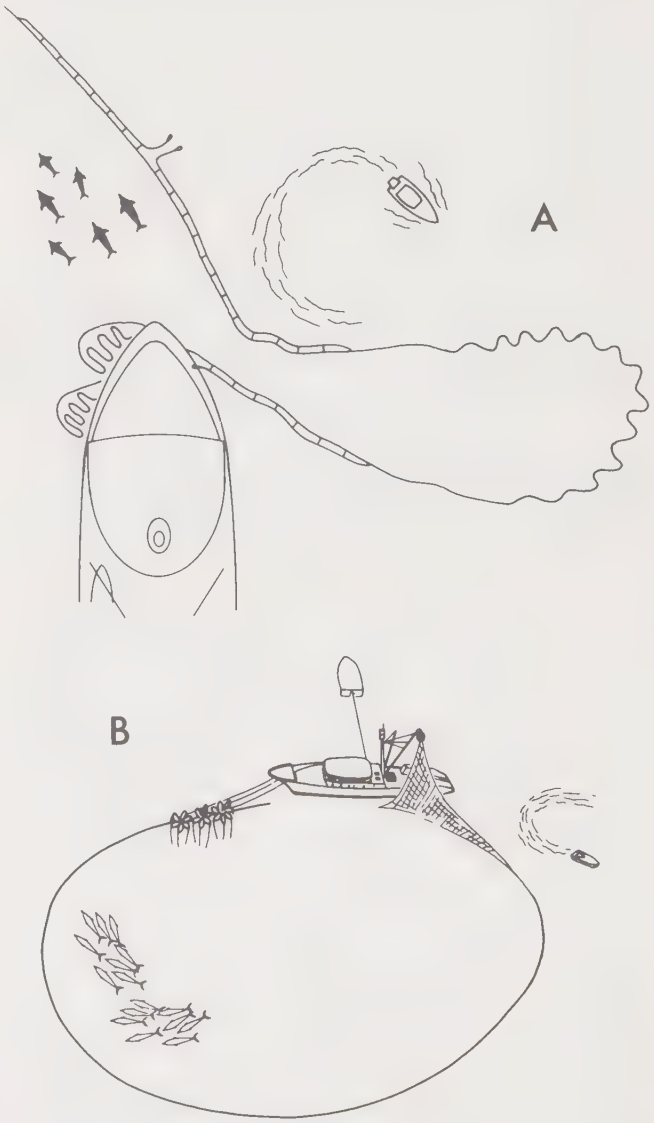


**Figure 11.—Use speedboats to prevent porpoise from (A) entering dangerous areas of the net and (B) from entering the area where the corks come out of the water during net roll. Corks make good sonar targets for the porpoise while 108 mm (4¼-in) mesh may not.**

discourages porpoise from approaching that area. This tactic is useful for keeping porpoise out of potential danger areas such as bow and stern bends, the bow bunches, and where the net rises out of the water to the power block (Fig. 11). Speedboats should be used whenever possible to discourage porpoise from entering hazardous areas. Speedboats attached to the backdown apex during backdowns, however, should have their motors turned off.

## Equipment Malfunctions

The nature of purse-seining operations and the environmental conditions in which they are carried out can lead to gear and equipment breakdowns. These malfunctions do and will continue to occur somewhat routinely on all tuna seiners. They cause porpoise mortality directly through critical breakdowns and indirectly through delays in the net-retrieval procedures. During the period 1977-79, an average minimum of 5.6% of the observed mortality was directly due to equipment breakdowns and gear malfunctions. During this 3-yr period, observed sets with delay-causing malfunctions averaged 19 min longer than sets with no malfunctions.

The role of malfunctions as an indirect cause of mortality may be more important than that of direct causes. The direct influence of hydraulic failures, broken lines, and cables can be readily assessed. But when a malfunction causes an operation slow-down, or change in the net configuration, it is difficult to assess the subsequent contribution to mortality. Therefore, mortality in sets with malfunctions may be attributed to other, more directly observable causes of kill (e.g., net collapse). The percentage of the total observed kill directly caused by malfunctions (5.6%) must therefore be considered a bare minimum.

Table 3 lists the major malfunction categories, frequency of occurrence, percent of malfunction-related kill, and the average delay associated with each. While elimination of all malfunctions is not a reasonable expectation, the frequency and severity of some may be minimized through careful maintenance and inspection schedules.

The proper functioning of a seiner's mechanical equipment is essential both for catching tuna and for safe maintenance and effective release of porpoise. While no specific technology has been developed to reduce the incidence of mechanical failures, machinery critical for porpoise fishing should be inspected more regularly while on the fishing grounds. Maintaining a routine visual inspection and repair policy for all net retrieval systems and speedboats will reduce porpoise kill rates. The most common equipment malfunctions involve speedboats, hydraulic systems, the seine skiff, the various winches, and cable or line failures.

Another class of malfunctions does not necessarily involve the failure of a mechanical system; rather, they result from an ill-defined combination of vessel net characteristics, operator actions, and environmental conditions. These problems include roll-ups (webbing wrapped tightly around the purse cable, preventing pursing) and the entangling of the purse rings in the webbing (preventing net retrieval, after pursing). The propensity for roll-ups seems to be vessel specific and, although a wide variety of informal information on their cause and prevention exists, no technological solution has been devised. In fact, the specific physical causes of roll-ups are not yet fully understood. Tactical methods for avoiding entangling the purse rings in the net may be successful. However, those tactics would be as variable as the environmental circumstances (winds, current profile) which cause the problem. These circumstances and their specific effects have yet to be fully defined.

# PORPOISE RELEASE

Backdown is the only proven technique for the wholesale release of captured porpoise. It is also the activity which causes a large share of the porpoise mortality (42% of the kill in sets with kill greater than 15, Table 2). The procedure forces porpoise into contact with the webbing of the floor, side walls, and apex of the channel. Here they may become entangled individually in the meshes, hangings, and holes, or they may become entrapped, en masse, in folds and canopies of loose webbing. Primary factors affecting porpoise mortality during backdown are the configuration of the backdown channel prior to and during backdown, the skill and effort of the captain and crew, the condition of the net, and the behavior of the fish and porpoise. A carelessly executed backdown virtually guarantees high porpoise kill and increases the probability of accidental fish loss.

## Condition of Net and Equipment

Failures of hardware components cause loss of valuable fishing time and can lead to the loss of tuna and even other pieces of equipment or the net itself. Similarly, gear failures contribute to kill rates both prior to and especially during backdown. Some commonly occurring gear and equipment problems that contribute

**Table 3.—Major malfunction categories showing frequency of occurrence, percent of minimum malfunction-related mortality, and average delay of set for each of the 3 yr of this study.**

| | 1977 | | | 1978 | | | 1979 | | |
|---|---|---|---|---|---|---|---|---|---|
| Malfunction | No. sets | Kill % | Avg. delay (min.) | No. sets | Kill % | Avg. delay (min.) | No. sets | Kill % | Avg. delay (min.) |
| Speedboats | 120 | 9 | 1 | 78 | 2 | 1 | 82 | 13 | 1 |
| Purse cable | 94 | 13 | 18 | 27 | 15 | 12 | 22 | 24 | 16 |
| Hydraulic problems | 73 | 5 | 22 | 44 | 5 | 28 | 17 | 5 | 18 |
| Skiff | 63 | 18 | 23 | 35 | 8 | 16 | 29 | 21 | 18 |
| Winch and ring stripper | — | — | — | 12 | 2 | 18 | 6 | 3 | 42 |
| Roll-up | 151 | 12 | 34 | 59 | 12 | 47 | 39 | 17 | 53 |
| Net tangled in rings | 129 | 13 | 16 | 42 | 29 | 19 | 31 | 5 | 15 |
| Bow bunches | 41 | 5 | 6 | 37 | 2 | 16 | 22 | 6 | 15 |
| Other | 144 | 25 | 20 | 44 | 25 | 12 | 23 | 6 | 16 |
| Total | 815 | 100 | 19 | 378 | 100 | 19 | 271 | 100 | 19 |

to backdown-related mortality are set out below with discussions and recommendations where applicable.

**Corkline Hangings.**—During backdown the weight of the net pulling down on the hangings forms openings between the webbing and the corkline. The 20 fathoms of corkline on either side of the backdown apex are subjected to the greatest downward pull during backdown and at the same time are subjected to maximum porpoise contact. The porpoises' beaks and flippers get caught in these openings, holding the animals securely until they drown or are rescued.

All hangings above the porpoise safety panel and porpoise apron should be tight enough so as not to permit a cylinder of 35 mm (1-3/8 in) diameter to be inserted between the webbing and the floats or corkline. As the fishing season progresses, knots tighten, floats are abraded and compressed, and hangings break, thus producing an increasing number of dangerous openings during backdown. Porpoise caught in these openings increase the job of the rescuers and add to the length of the set. It is strongly recommended that operators ensure that the corkline hangings around the backdown apex are regularly checked by the raft man and maintained in the best possible condition. This task can be simplified by placing the backdown area floats on a lighter auxillary corkline "Medina corkline" and lacing the webbing directly to the main corkline.

**Holes in Webbing.**—Shark bites, porpoise and fish entanglement, snags during setting and retrieval, as well as many less common abuses contribute to the creation of holes of varying size in the porpoise safety panel and apron. Holes in the backdown area of the net allow fish to escape, porpoise to be drowned, and, because they cause uneven distribution of loads in adjacent areas, tend to get bigger or contribute to the formation of other holes. Aside from the bunt end and the rolling strips, the webbing in the backdown apex bowl (apron and first safety panel strip, Fig. 12) receives the most wear and tear and should get maximum attention for marking and mending of holes. Careful attention should also be given to the lacings between the webbing strips on a vertical line from the backdown apex to the chain since a good deal of the strain of backdown is along this line (Coe and Butler 1980).

The age and degree of use of the webbing in the safety panel and apron greatly affect its resistance to tearing. Three to four years seems to be about the operational life of an apron. It is preferable to replace worn out aprons with new webbing. Segments (bales) in the safety panel can be exchanged from areas of high wear to areas of low wear, to help prolong the service life of the entire panel.

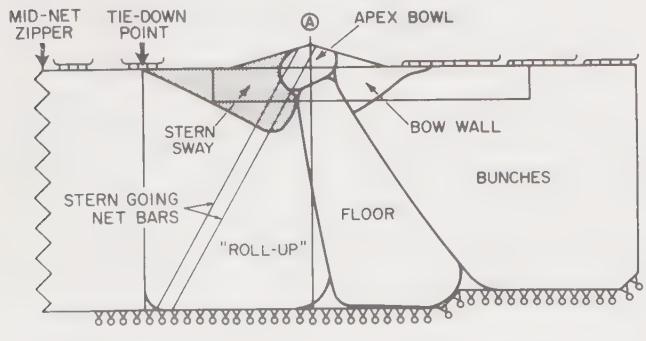


**Figure 12.—Functional distribution of webbing in a stabilized backdown channel.**

**Bow Bunch Failure.**—One of the most rapidly wearing components of the backdown system is the outermost bow bunchline. These lines suffer serious abrasion along most of their length by being hauled under load through small diameter steel rings and by being wrapped on a capstan to achieve this hauling power. Typically, bunchlines are 28.6 mm (1-1/8 in) three-strand, twisted nylon rope. After being hauled into its proper position the bunchline is bent sharply over the port rail and secured around a 305 mm (12-in) cleat. The outboard end of the bunchline is usually fastened to a pear link or swivel link and chain by means of a clove-hitch and back-splice. These practices break several basic rules of safe rope use and virtually guarantee a short working life of the outermost bow bunchline.

When the bow bunchline breaks during backdown, backdown must be stopped, the channel collapses immediately, and canopies develop everywhere leading to unavoidable mortality. Under these circumstances the bunchline must be temporarily retied or replaced on the spot, a procedure which is always difficult and often impossible depending on the location of the break. If the bunchline cannot be quickly refitted, the alternative then becomes to release the tie-down, roll an amount of net equivalent to the length of the broken bunch, tie-down again, and back out whatever animals are still left alive in the net.

The probability of breaking the outermost bunchline can be reduced to near zero by handling it slightly differently than is the most common practice. First, use an eye splice with a thimble to connect the bunchline to the swivel or pear link at the outboard end (this may require an increase in the diameter of the outermost bunchline rings). Second, provide a fairlead, roller, or bullnose on the port rail with a diameter three to four times that of the bunchline (10-13 cm; 4-5 in). Third, secure the outermost bunchline on the bow mooring bitt rather than to a cleat. Any sharp bend in a rope under load decreases its strength and may cause premature damage or failure. Most port-side rails and bow cleats in the U.S. fleet create sharp bends and thus contribute to bunchline failure. Even with these precautions, ropes can fail and, so, should be regularly inspected for signs of wear and damage. Further, the terminal chain, its component parts, and bridle splices to the corkline should be examined for weakness or damage on a regular basis. Making the modifications suggested above and frequently inspecting the bunchline and connections will virtually eliminate the infrequent but usually costly consequences of bunchline failure during backdown.

**Vessel Control Systems.**—These systems are vitally important to the efficient execution of all phases of purse seining, and failure or malfunction in any of them wastes valuable time and contributes to high porpoise kill. Control systems of particular importance for backdown execution are: 1) The net skiff and its towline, 2) the bowthruster and its controls, 3) the vessel gear selector and throttle control, and 4) the rudder control.

## Configuration of the Net for Backdown

**Dynamics of Backdown.**—Any systematic effort to reduce porpoise mortality requires an understanding of the dynamics of the backdown procedure. While each net is different in one respect or another, all nets respond similarly during backdown because they are all constructed of physically similar units (rhombic meshes) oriented in the same direction, with similar external forces working on them. Backing down essentially tows the net by the two ends of the corkline and by the entire bottom of the net (the chain and ring bridles). To achieve the backdown channel

configuration that is least likely to kill porpoise, the length of corkline in the water from the outermost bow bunch to the stern tie-down point must be just right. That length is solely determined by the stretched depth of the individual net.

If too little corkline is left in the water, a large apex canopy will form, drowning many porpoise (Fig. 13a). If too much corkline is left in the water for backdown, the apex will fold and wrinkle, and the corks will be difficult to sink (Fig. 13b; McNeely and Holts 1977[10]). When the proper bow and stern tie-down points are used, the backdown apex forms a bowl of fairly taut, open meshes that slopes gently away from the vessel and has no surface canopies. The apex bowl is developed as the water flows against the mesh (apron) at the end of the loop. This bowl is held in place by its connection to 1) the corkline, 2) the vertically stretched webbing between the rings and the apex, and 3) the stern-going net bars from the apex to the chain (to the left in Fig. 12). This 3-point connection is the reason why the stretched depth of the net is so critical in calculating the length of corkline necessary for an optimum backdown channel.

As backdown begins, the net is pulled through the water, causing the meshes to elongate and the net floor to rise. The resistance to the lift being exerted on the net floor results in a downward force sufficient to sink the corkline at the channel apex. This localized sinking is augmented by the weight of porpoise against the webbing below the apex corkline, facilitating porpoise release.

The net floor usually reaches its shallowest point after about 11 min of backing down (Coe and Butler 1980). At this time the subsurface configuration of the backdown channel becomes very stable and the apex corkline becomes more difficult to sink. Every effort must be made to release the captured porpoise as early in backdown as possible. Figure 12 shows the approximate distribution of functional areas of webbing in a stabilized backdown channel (Coe and Butler 1980). Note that the line of force pulling the net through the water causes a large triangle of webbing below the apex and the stern-going net bars to "roll-up" into a long thin sausage shape which spreads out to form the apex bowl. To the bow side of this sausage is the channel floor, which is flat and taut and reaches over to the deeper pocket formed by the slack webbing under the bow bunches. From the stern side of the sausage rises the stern wall which is forced into the channel by the oblique flow of water. The stern wall thus overlaps the sausage and part of the net floor, forming the subsurface canopy known as "stern sway"[11] (Figs. 12, 14). Stern sway disappears where the sausage opens out to form the apex bowl. At present, stern sway is an unavoidable feature of backdown, and may entrap porpoise that stay deep in the channel and fail to move to the apex area as backdown progresses. The faster and more deliberately the early stages of backdown are executed, the less likely it is that animals will become trapped in the stern sway.

**Tie-Down Point Formula.**—All vessels installing aprons should perform a water haul (trial set) to locate the proper bow and stern tie-down points for backdown. This insures that the apron apex coincides with the actual backdown channel apex. In order to assist vessel captains and net makers who cannot make trial sets, a series of net measurements for approximating the optimum tie-down points for their nets has been carried out. The results of this work show that the optimum apex to stern tie-down distance is equal to the stretched net depth plus the length of one ring bridle plus the distance from the ring stripper (center) to the point on the port rail where the net is tied during backdown (Fig. 15).[12] It is strongly recommended that the net be tied down as far aft of the ring stripper as possible. The error for this calculation can be up to 3 fathoms, so some minor adjustments to suit individual nets and captains may have to be made after setting the tie-down point.

Table 4 lists the approximate distance from the backdown apex (center of the apron) along the corkline to the correct stern tie-down point for various net depths. When this measurement has been made and the stern tie-down point marked, the outermost bow bunchline can then be adjusted to align the balloons at the apron ends, thereby establishing the bow bunchline mark for a properly aligned backdown channel. From this point, minor adjustments can be made based on net performance and the cap-

[10]McNeely, R. L., and D. B. Holts. 1977. Methods of reducing porpoise mortality in the yellowfin tuna purse seine fishery. Southwest Fisheries Center Admin. Rep. LJ-77-13, 19 p.

[11]Unpublished Cruise Report: M/V *Margaret L.*, May 19 to September 11, 1977. On file at the Southwest Fisheries Center, Oceanic Fisheries Resources Division, P.O. Box 27, La Jolla, CA 92038.

[12]Unpublished Cruise Report: M/V *Maria C.J.*, September 12 to December 28, 1980, 25 p. On file at the Southwest Fisheries Center, Oceanic Fisheries Resource Division, P.O. Box 271, La Jolla, CA 92038.

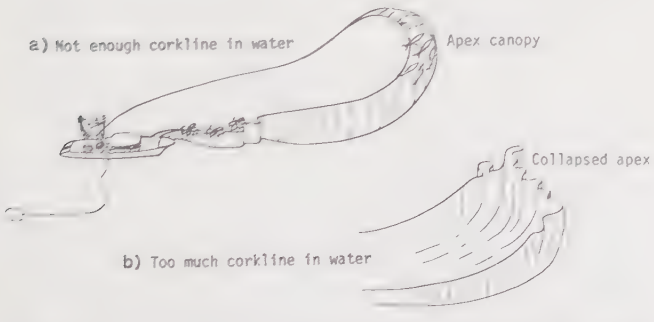


**Figure 13.—To ensure the proper amount of corkline for backdown, clearly mark tie-down points for the net and last bow bunch pulled. Never estimate these points. The proper amount of corkline is directly related to the depth of the net. Too little corkline (a) in the water will result in apex canopies. Too much corkline (b) will produce a collapsed and wrinkled corkline.**

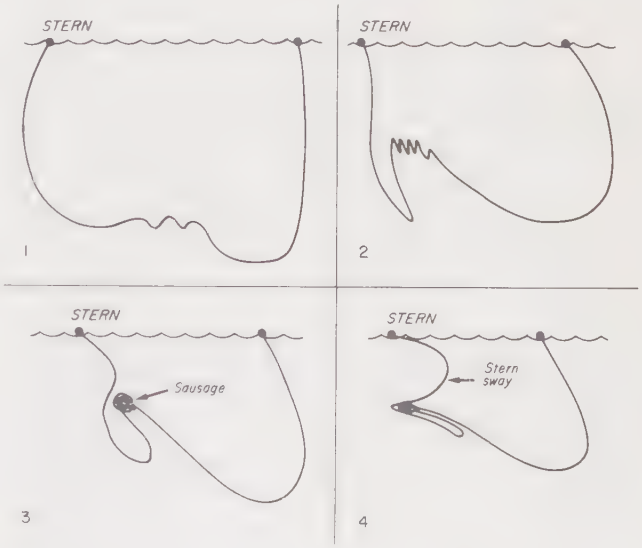


**Figure 14.—Backdown channel cross section showing development of stern sway during backdown.**

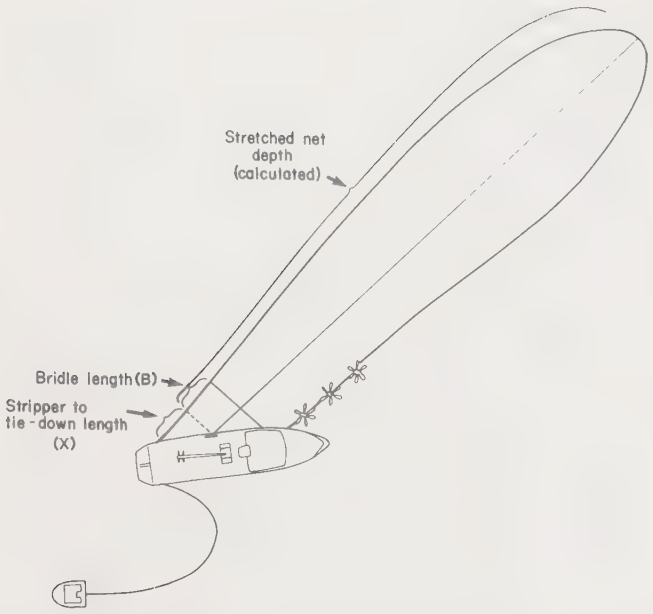


**Figure 15.—Determining proper tie-down points for backdown: The sum of the calculated stretched depth (in fathoms), the length of one ring bridle, and the distance from the ring stripper to the point on the vessel where the net is tied down, gives the tie-down point within 4 or 7 m (2 or 3 fathoms).**

**Table 4.—Calculated distance in fathoms along the corkline from the apron apex to the stern tie-down point. This table is based on nets with 7 to 16 horizontal strips (not counting apron) of 108 mm (4¼ in) stretched mesh web 100 meshes deep plus 2 strips of 32 mm stretched mesh web of 340 meshes with an apron and a salvage 10 meshes deep of 127 to 203 mm (5 to 8 in) stretched mesh and a single purse ring bridle leg of 4 m (2 fathoms).**

| No. of net strips | Stretched depth (fathoms) | Distance; apex to stern tie-down (fathoms) |
|---|---|---|
| 9 | 62.8 | 62.8 + $X$[1] |
| 10 | 68.7 | 68.7 + $X$ |
| 11 | 74.6 | 74.6 + $X$ |
| 12 | 80.5 | 80.5 + $X$ |
| 13 | 86.4 | 86.4 + $X$ |
| 14 | 92.3 | 92.3 + $X$ |
| 15 | 98.2 | 98.2 + $X$ |
| 16 | 104.1 | 104.1 + $X$ |
| 17 | 110.0 | 110.0 + $X$ |
| 18 | 115.9 | 115.9 + $X$ |

[1]X = distance in fathoms from center of ring stripper to the tie-down location on the port rail (e.g., $X$ = 0 if tie-down is under the ring stripper).

tain's preference. This method of establishing tie-down points for backdown is independent of the number of bow bunches pulled. It is based solely on the stretched depth of the net and a known backdown apex location.

The formula for calculating stretched net depth (*SD*) in fathoms as presented in Table 4 takes the form:

$$SD = \frac{(A + B) + \sum_{i=1}^{n} Y_i Z_i}{72}$$

where $n$ = the number of webbing strips of any size or depth between the apron and the chain,
$Y_i$ = the number of meshes deep in the $i$th strip,
$Z_i$ = the stretched mesh size in the $i$th strip in inches,
$A$ = the stretched depth of the apron in inches (500-550 or, 0 if no apron),
$B$ = the length of one leg of a ring bridle in inches.

For example, the *SD* of a hypothetical net 15.5 strips deep with no apron and varying mesh sizes would be calculated by the following steps. Starting at the corkline and working down to the leadline (note as a convenience to net makers these calculations are presented in fathoms and inches):

| | |
|---|---|
| 1. Apron depth ($A$) no apron | 0 in |
| 2. Two strips, 1¼-in mesh, 340 meshes deep (2 × 340 × 1.254) = | 850 |
| 3. Three strips, 3-in mesh, 140 mesh deep (3 × 140 × 3) = | 1,260 |
| 4. Four strips, 4¼-in mesh, 100 meshes deep (4 × 100 × 4.25) = | 1,700 |
| 5. Six and one-half strips, 5-in mesh, 100 meshes deep (6.5 × 100 × 5) = | 3,250 |
| 6. One salvage strip, 8-in mesh, 20 meshes deep (1 × 20 × 8) = | 160 |
| 7. Single ring bridle length ($B$), 3 fathoms (3 × 72 in/fathom) = | 216 |
| 8. Adding items 1 to 7 = | 7,436 in |
| 9. Dividing 7,436 in by 72 in/fathom yields: | *SD* = 103.28 fathoms |

By following this method, the stern tie-down point to backdown apex distance on the corkline can be approximated for any net and vessel combination by adding the distance, in fathoms, from the center of the ring stripper to the tie-down location on the port rail ($X$ in Table 4 and Fig. 15). It is absolutely essential that the net structure (strips, meshes deep, and mesh size) between the backdown apex and the chain be known precisely.

**Porpoise Safety Panel.**—Since 1977, Federal regulations have required a 32 mm (1¼-in) stretched-mesh safety panel in the backdown area. The employment of small mesh protection against entanglement (Barham et al. 1977) has been a major factor contributing to the drastic reduction of average kill rates from 1976 to the present.

The required safety panel for most seiners is a minimum of 330 m (180-fathom) stretched length (before installation) by two full strips of 32 mm mesh. Typically, the safety panel consists of six bales of webbing, each 110 m (60 fathoms) long by 340 meshes deep, laced together in a rectangle 3 bales long and 2 bales deep (Fig. 16). Because 340 meshes of 32 mm stretched mesh webbing is equal in depth to 100 meshes of 108 mm stretched mesh (a standard production size), the safety panel is conveniently installed by replacing the top two strips of 108 mm mesh directly below the corkline around the backdown channel (Fig. 17). The specific location of the safety panel in the net is partially determined by Federal regulations in that it must cover at least two-thirds of the stern side of the backdown channel and extend around the channel to a point 110-183 m (60-100 fathoms) from the bow end of the net (ortza). The bow end of the safety panel should completely cover the outermost bow bunch that is pulled for backdown. Further, all operators must understand that the length of corkline around the backdown channel is dependent on and determined by the stretch depth of the net (see Tie-Down Point Formula). This is true even if the net does not have an apron.

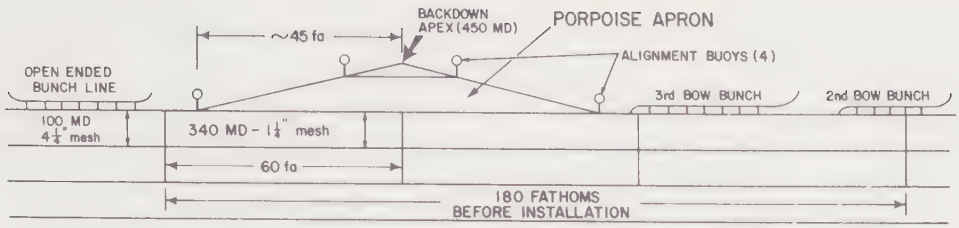


**Figure 16.—Configuration of porpoise safety panel and super apron.**

**Figure 17.—Porpoise safety panel (PSP) must cover the perimeter of the backdown channel, at least from the last bow bunch pulled, around the apex and sternward at least two-thirds of the distance back along the sternside of the channel.**

For those seiners without aprons, having more than one set of tie-down points can be useful. In order to backdown successfully with varying numbers of bow bunches pulled, pairs of clearly marked tie-down points must be established for each apex location desired. The safety panel should be lengthened to ensure complete coverage of the backdown channel's perimeter in each backdown configuration. The pairs of marks (stern-side corkline and outermost bow bunchline) must be clearly distinguishable (numbered or color coded) to avoid serious errors in tie-down combination (Fig. 18).

**Super Apron.**—The super apron, or simply the apron, as it has come to be known, is a triangular-shaped section of 32 mm (1¼-in) webbing approximately 165 m (90 fathoms) long at the base and 450 meshes high at its peak (Fig. 16). It is installed between the corkline and the upper edge of the porpoise safety panel in a location that places the peak of the triangle at the desired backdown channel apex. The apron has several advantages in that during backdown it forms an inclined ramp which helps deliver the porpoise to the release area at the backdown apex, it reduces the tendency for slack webbing to develop into canopies along the sides of the backdown channel near the apex, and it adds another strip-and-a-third of small mesh to protect the floor and sides of the channel from porpoise entanglement. Another positive feature of the apron is that its required use has forced vessel operators to locate and use their optimum tie-down points. This has certainly resulted in far fewer porpoise deaths due to unnecessary canopies in poorly configured backdown channels.

The construction of an apron requires one 110 m (60-fathom) by 340-mesh bale of 32 mm webbing. Instructions for building and installing an apron are provided by Holts (1977[13]).

## Executing Backdown

The use of right rudder, thrusting to port, and briefly towing the stern to starboard with the skiff at the start of backdown can help to quickly set up the channel in the correct position for porpoise release. The skiff and bowthruster should be used as needed prior to tie-down to gently begin stretching the net and positioning the vessel for the start of backdown. This pre-forming of the channel will help ensure that porpoise are at or near the apex when backdown begins, thus contributing to rapid, en masse release.

Care must be taken to ensure that the net will not fold in on itself when backdown begins because this malformation of the channel can result in high kills.[14] Therefore, the captain should use a speedboat to pull the corkline out whenever it is folded into the channel (Fig. 19). Bunchlines must be arranged so that the bow bunches are evenly spaced and fall in the natural line of the bow corkline from the apex to the breastline attachment. Improperly aligned bunches will either reduce the volume of the bow

[13]Holts, D. B. 1977. The super apron system: Construction and installation. Southwest Fisheries Center, Admin. Rep. LJ-77-30, 12 p.

[14]Unpublished Cruise Report: M/V *Bold Contender*, September 22 to December 4, 1975, 13 p. On file at the Southwest Fisheries Center, Oceanic Fisheries Resource Division, P.O. Box 271, La Jolla, CA 92038.

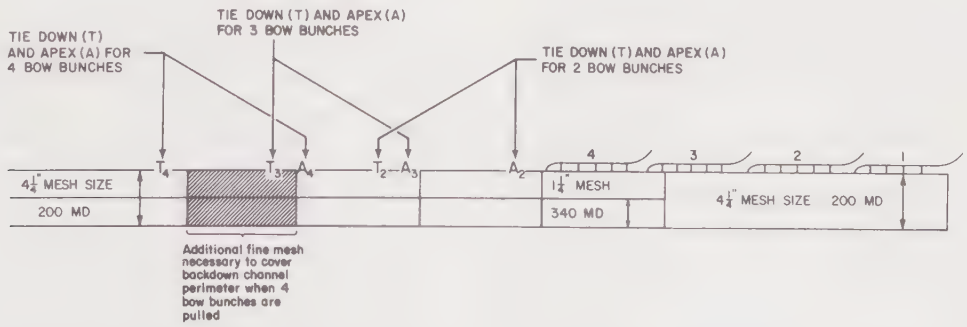


**Figure 18.—Multiple tie-down points for backdown in nets without aprons when using 2, 3, or 4 bow bunches. Remember to avoid placing bunchlines within 18 m (10 fathoms) of any of the apex markers.**

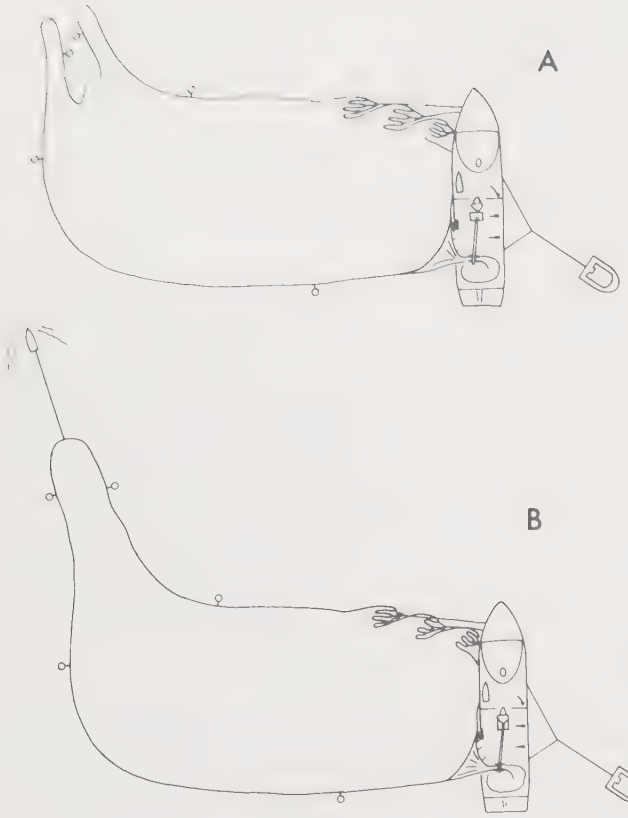


**Figure 19.—Straighten out the channel apex before backdown. Do not attempt backdown when the apex is folded into the net. Use a speedboat to pull out collapsed section before attempting backdown.**

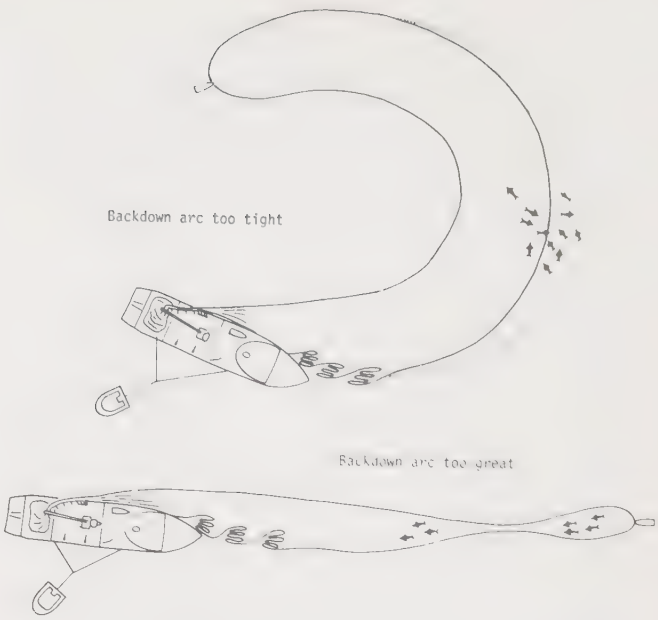


**Figure 20.—Proper backdown arc insures efficient waterflow to maintain a wide and deep channel. Maintain correct radius of turn by changing the pulling position of the net skiff, rudder angle, and direction of bow thruster as necessary.**

side pocket for the fish or create canopies along the bow wall of the channel, both of which increase the difficulty of backdown and increase the probability of porpoise kill. The outermost bow bunch should be positioned no farther out in the channel than one-third of the distance from the bow to the apex and should be fully protected by the porpoise safety panel.

Maintenance of an open and canopy-free backdown channel requires careful control of the arc that the vessel makes while towing the net (McNeely and Holts footnote 10). This natural arcing tendency can be reduced or augmented depending on its suitability for channel operation. If the arc is too tight (i.e., the channel is too curved), bow side canopies will be present and the corkline won't sink at the apex (Fig. 20a). If the arc is too straight, the channel will quickly collapse and porpoise will create canopies by being overcrowded (Fig. 20b).

Not infrequently the lack of adequate communication between the captain and the speedboat operator at the backdown apex has resulted in either accidental fish loss or the failure to release all of the captured porpoise. This problem is particularly apparent during night backdowns when hand or flashlight signals are difficult to see and interpret. To relieve this problem, two-way radio communication may be set up between the apex-tending speedboat operator and the captain. During night backdowns a powerful floodlight should be continually shown in the area of the bow bunches in order to attract and possibly hold some of the fish in the net pocket below the bunches. A hand-held spotlight should be used only as needed by the speedboat driver at the apex to determine how many porpoise remain in the net. Intermittent spotlighting of the apex area from the main vessel should be kept to a minimum as it temporarily blinds the speedboat operator and any rescuers in the area. Floodlighting of the entire net using a diffuse light source may eliminate some of the problems caused by poor visibility during night backdowns.

Another speedboat can be used during backdown to circle in the area of the bow bunches and discourage porpoise from swimming upstream, away from the apex release area. The backdown operation should be continued until all the porpoise are released. Since the apex corks become progressively harder to sink after the channel stabilizes (about 11 min), aggressive, nonstop backdown should be continued as long as there are enough porpoise in the net to plug the apex and prevent fish release. As the channel narrows, the release area gets smaller, and requires fewer porpoise to fill in the release area and prevent fish loss (Coe 1976[15]). Thus rapid backdown can continue until very few porpoise are left in the net. These are general recommendations and must be tailored to particular circumstances in the field.

Rescue by hand should be continued to ensure that zero-kill sets occur as frequently as possible. Diving and depth recording instruments show that within 1 min after the vessel stops backdown, the channel floor sinks from 4-6 to 20-25 m. This rapid increase in net volume gives any live porpoise remaining in the net a tremendous amount of space in which to avoid rescue attempts. For this reason, backdown should be continued, at least slowly, until rescuers have removed all live porpoise from the net.

When all the captured porpoise have been released it is common practice to release or partially release the outermost bow bunchline. This action takes the tension off the apex area of the channel and helps to ensure that the corkline will not accidentally sink and release fish. The vessel should continue to backdown slowly until the wind is on the port bow. At this point backdown can stop and net retrieval can be resumed.

[15]Coe, J. M. 1976. The effectiveness of the porpoise apron in improving the backdown prodecure. Southwest Fisheries Center, Admin. Rep. LJ-76-38, 17 p.

## Porpoise Behavior During Backdown

There are several aspects of porpoise behavior that are relevant to their release or rescue during backdown. This information is presented so that participants in the fishery may have a better understanding of some of the causes of mortality that are uncontrollable as well as the behaviors that supplement the release and rescue efforts.

Most porpoise (especially spotters) display a behavior termed "rafting" (Norris et al. 1979[16]). Rafting occurs when individuals or groups of porpoise remain at the surface or just below it for long periods of time with a minimum of swimming and virtually no diving activity. Typically, the rafting animals are motionless at the surface with the head up and tail down. Rafting groups can involve any proportion of the school and are nearly always composed of pure spotters. Rafting usually begins after the rings are up and increases until backdown disrupts it.

Since rafting animals move very little, they can be positioned at or near the apex for the start of backdown by using the skiff to slowly stretch the bow corkline during net rolling and pull the net to the porpoise. When backdown begins the rafting groups drift up to the corkline where they may become more active in an attempt to avoid the advancing wall of net. By this time it is too late for the rafting animals to avoid the net because those nearest the vessel keep drifting against the animals nearest the apex, forcing their release over the corkline. It seems that as long as there are rafting animals on the boat side of the porpoise at the apex corkline and there are no major disturbances to cause these rafts to break up, this "passive crowding" effect will operate and the porpoise will be easily released. Unnecessary noise or other stimulation during the set should be avoided in order to enhance the generally inactive state of the porpoise and get the maximum benefit from passive crowding during backdown.

Backdown release becomes more difficult when the remaining porpoise are aware of the advancing apex corkline. At this point the animals will swim upstream, away from the apex where they may fight the net at the surface (or at depth), passively allow themselves to be dragged along with the net, or actively attempt to get over the corkline.

Porpoise in the captured school either swim actively from the advancing wall of the net, raft, or display what is termed "passive" behavior (Coe and Stuntz 1980). During backdown there are occasionally some animals that sink and lie on the webbing and many more that show signs of the sinking behavior and drop out of the rafting groups. At first glance, the animals appear to be struggling feebly, perhaps against the current being produced as the seine is pulled through the water during backdown. Their movements are weak and lack the grace that one expects in porpoise. After about 3-5 min, the passive porpoise begin to rise singly or in two's and three's to breathe and are either backed out of the net or hand-released if the backdown procedure has already been terminated. Animals usually do not return to rest on the bottom of the net after surfacing.

When viewed from a speedboat tending the corkline in the release area during backdown, animals may appear to be dead, and as a result the release efforts may be prematurely terminated. Porpoise not released during backdown have a high probability of being killed. The reasons for passive behavior in purse seine-caught spotters are not fully understood and this behavior has only rarely been observed in spinners.

Porpoise cannot swim backwards. Once in a canopy they rarely get out unless they either sink free due to exhaustion or passive behavior, are rescued, or have the canopy pulled past them such as in a bow or stern wall canopy during backdown.

A very large catch of fish may cause fragmentation of the porpoise school and result in groups being caught in the meshes deep in the net prior to backdown. Large catches may also cause some of the porpoise to enter deep canopies near the boat during backdown or to get caught under the bow bunches. Little can be done to avoid these occurrences, but increased rescue effort, such as using a second raft, may help to minimize the resultant mortality. The number of porpoise killed in a set is highly correlated with the amount tuna caught. That is, with increasing tuna catch one can expect release to be more difficult, increased rescue effort to be necessary, and a higher likelihood of unavoidable kills.

## Trouble Shooting Backdown Performance

Skipper interviews, observer data, and field observations point out several common and recurring problems with backdown performance. These are identified and discussed in this section.

1. Inability to sink the corkline at the backdown apex is one of the most common and frustrating problems that occurs. It causes higher than normal kill rates, protracted backdown times, and high levels of hand-rescue effort. There are two causes for this complaint. The most frequent is the stabilization of the channel configuration after 10 or 11 min of backdown. Stabilization of the channel is unavoidable due to the physical structure of the net and its reaction to induced water flow. However, there are several techniques to help reduce its consequences.

First, backdown faster and more aggressively before the channel stabilizes, so that most, or all, of the porpoise are out of the net while the corks will still sink.

Second, slightly more downward force on the corkline can be generated after stabilization by having a little less corkline in the water. Shorten the corkline in the backdown channel by increments of 1 fathom at both the stern and bow bunchline tiedown points. Continue shortening the corkline in this manner, 1 fathom during each set until the desired results are achieved. If a slight canopy forms at the apex, slack off a few fathoms from both the bow and stern and discontinue this method.

Third, assuming the remedies outlined above failed to produce the desired results, begin removing flotation from the apex area. Do this carefully and only as a last resort, because removing floats to enhance late backdown sinking will enhance the ease of sinking and the difficulty of raising the corkline in early backdown.

2. Surface canopies are a common cause of porpoise mortality during backdown. In a properly configured backdown channel, they are ordinarily formed when the porpoise swim against the webbing along the walls of the net. In the case of canopies on either side of the channel, the captain's most immediate job is to continue backing down as fast as possible to cause the animals to slide down the channel toward the apex. If there is a canopy at the apex of the channel, then the net is improperly tied down and more corkline must be put into the loop. This should be done in steps of 2-4 m (1-2 fathoms) from both bow and stern until the apex canopy no longer forms. In any particular instance an apex canopy can usually be relieved by slacking the outermost bunchline a few fathoms and continuing the backdown. However, adjustment of this bunchline during backdown is not a solution to

[16]Norris, K. S., W. E. Stuntz, and W. Rogers. 1978. The behavior of porpoises and tuna in the eastern tropical Pacific yellowfin tuna fishery-preliminary studies. Available U.S. Dep. Commer, Natl. Tech. Inf. Serv., Springfield Va., as PB 283970, 86 p.

consistent apex canopy problems. Adjustment of the stern corkline mark and the outermost bow bunchline mark to put more corkline in the water should permanently solve the problem.

Major bow-side canopies are usually the result of too tight an arc for backdown, which causes an oblique water flow and pulls the bow corkline over the surface of the channel. The use of more right rudder to decrease the backdown arc is useful in straightening out the channel while continuing to backdown.

Consistent bow-side canopies may be due to differences in hang-in rates caused by the improper installation or reinstallation of a porpoise apron that required the "killing-in" of large amounts of webbing. Check the hang-in in any areas with consistent localized canopies and correct it so that the entire bow wall has the same hang-in rate.

Stern wall canopies during backdown are almost entirely caused by the porpoise themselves due to crowding or in avoidance of fish. At present there is no remedy other than to continue rapid backdown to flush the porpoise to the apex and to check the hang-in rates in areas with consistent localized canopies.

Once begun, backing down should never be completely stopped because the tension goes off the meshes and animals can then push against the webbing and form a canopy anywhere in the net. By the time backdown is resumed, it may be too late to back the animals out of their self-formed canopies. This same problem occurs with tuna and can result in pockets of dead fish that slow net retrieval after backdown. Furthermore, if porpoise hit the net in areas of 108 mm (4¼-in) mesh while it is slack, their beaks will go through and when tension is reapplied, the mesh will stretch and close, holding the animal in place.

3. Backdown-channel collapse is a fairly common occurrence at the end of the maneuver and is usually only partial. If all or nearly all of the porpoise are out of the net at the time of partial collapse, it is of little consequence and, in fact, helps rescuers get their hands on the stragglers for quick rescue. Once the wind is on the port bow and net rolling begins, the channel should open immediately, providing room for the live fish to circulate.

If channel collapse occurs early and consistently in backdown, the cause is usually too little arc in the path of backdown (i.e., it is too straight) and is remedied by moving the rudder more to port and, if necessary, thrusting the bow to starboard (McNeely and Holts footnote 10). Channel collapse, especially at the apex, can occur if too much corkline for the amount of webbing is in the water. This can be remedied by shortening the corkline by increments of 2 fathoms. This must be done carefully since pulling too much corkline, or pulling it unevenly, will create canopies at the apex.

If increasing the backdown arc and shortening the corkline loop do not solve the early backdown-channel collapse problem, the stern tie-down location may be removed as far aft on the port rail as possible. If this is done, the stern tie-down mark will also have to be moved an equal distance.

4. Sinking of the corkline on the bow side of the channel in the early stages of backdown is usually a harmless though aggravating characteristic of the backdown procedure. In some instances, where porpoise start to leave the net in this area, problems can develop when the net straightens out and these corks no longer sink. Some porpoise, expecting to follow those just released, can become entrapped under that area of the net. This problem can be reduced by trying to stretch out the bow corkline and getting the boat in line with it before applying power for backdown. The skiff can help orient the boat and stretch the bow corkline during net rolling just before backdown so that no time is wasted.

5. When these remedies have been tried without success or the solution to one problem gives rise to another, it is time to consider the balance of chain and corkline at the stern tie-down point. If the chain is 18-36 m (10-20 fathoms) ahead or behind the corkline at the tie-down point, the backdown channel may be seriously affected. Problems stemming from the corkline or chain consistently falling behind can usually be remedied by adjusting the angle of the power block. For example, when the corkline is falling behind the chain, adjust the power block to allow the chain to drop into the bottom of the "V" (inside) while the corkline is on the outside riding over the top of the webbing. This allows the corkline to come aboard at a faster rate than the chain. If the chain/corkline cannot be balanced in this way then a sling can be used to bunch 5-8 m (3-4 fathoms) of corkline at a time until the proper balance is achieved. The original stern tie-down mark on the corkline must be used to preserve the proper location of the backdown apex. Adjusting the corkline/chain balance only influences the amount of webbing and its configuration in the water.

## Porpoise Release Without Backdown

On the rare occasion where backdown cannot be performed, the only reasonable way to release the captured porpoise also releases the fish from the net. However unsatisfactory this alternative may be, it is recommended that it be carried out to avoid drowning most of the mammals. After the contents of the net are released, the cause for the inability to backdown can be repaired and, if enough daylight remains, the school may be recaptured.

To accomplish this release, roll the net until the area is approximately equal to or smaller than that for a normal backdown (depending on the number of porpoise captured), while trying to keep the net shape as rounded as possible. The bow ortza and breastline are passed to the net skiff and the bottom six to eight purse rings on the ring stripper are cut loose from their bridles. If possible, the breastline should be reattached at the ortza before transferring it to the skiff. If the bow bunches have already been pulled in, the bunch lines should also be passed to the skiff at this time. The skiff should then idle away from the bow to a distance of about 55 m (30 fathoms) and try to hold that position. If the skiff gets too far from the ring stripper, the chain (leadline) between the stripper and the skiff will rise, reducing the size of the opening for porpoise release. One or two speedboats should circle slowly outside the corkline on the stern side of the net to help move the porpoise toward the opening. It may take some time for the animals to start to leave the net. A raft and rescuer should be in the water on the stern side of the porpoise in case of entanglements or formation of canopies.

While the net is in this configuration, it is recommended that it be rolled to squeeze the porpoise out only as the very last resort, in which case more rings should be dropped. Since there is no skiff to control the position of the boat, rolling the net will cause the opening to become more shallow by pivoting the boat and may also force the porpoise into canopies as the stern moves toward them. Throughout this operation, the strength and direction of the wind will determine specifically how the skiff, vessel, and net will be maneuvered to maintain the release opening.

In the case where only a few porpoise have been captured, a raft man or two can attempt to rescue them by hand prior to opening the net. If they are successful in this attempt, any fish captured can be retained.

## PORPOISE RESCUE

Each tuna seiner engaged in fishing for tuna in association with porpoise should have at least one inflatable raft for use as a porpoise rescue platform during and after the backdown procedure (Coe and Vergne 1977). The following guidelines are recommended for raft use.

### Equipment for Raft Rescue

1. The raft should be at least 2 m long, with a double bladder inflating system which can be rigidly inflated and durable enough to withstand sun as well as deck and net abrasion. A back-up raft and repair kit should be on board.
2. A mask and snorkel are required to give the rescuer a clear view of underwater porpoise activity. Spotted porpoise occasionally "play dead" (passive behavior) by lying against the webbing during backdown and may be thought dead unless viewed underwater with a mask and snorkel. The raft man and his alternate should personally acquire their masks and snorkels to ensure proper fit. Low volume, three-window masks with a purge valve seem best suited for this activity.
3. A snap hook attached to the bowline of the raft about 2-4 m (1-2 fathoms) from the bow will allow rapid attachment and detachment from the corkline during rescue maneuvers. This hook should be used at all times during backdown.
4. Cotton gloves should be worn to give the necessary grip on the slippery beaks of the porpoise.
5. A wooden canoe paddle or its equivalent will allow the rescuer to paddle to the corkline.
6. The rescuer should be an experienced swimmer, who is individually motivated to get the live porpoise out of the net. One rescuer per raft is more efficient than two, because stability and mobility are maximized.

### Techniques of Raft Rescue

During backdown, the snap hook on the raft bowline should be attached to the corkline or webbing about 9-18 m (5-10 fathoms) from the apex on the stern side. From this vantage point the rescuer may observe the entire backdown and signal when the channel is clear of fish and when all live porpoise have been released. If the raft man is sufficiently skilled, he may paddle to the center of the channel and hold position, thereby helping to keep the porpoise from swimming upstream. In doing this, he should try to stay at least 10 m upstream from the closest porpoise.

As backdown nears completion, the rescuer should detach the raft, move to the apex of the net, and reattach so that he can disentangle and remove any remaining live animals. The rescuing process is made easier if the vessel continues slowly astern; this helps keep the porpoise at the end of the net and within reach. Every effort should be made to remove all of the live porpoise before ceasing backdown. Should any animals remain in the net after backdown, the rescuer can sometimes move down the corkline and drive the porpoise onto shallow webbing or back to the apex where they can be caught and released. Rescue efforts should be carried on until all porpoise are removed or the net skiff comes around. Although it is commonly done, using the raft after dark or leaving the raft to rescue porpoise by swimming is not recommended. At any time during a set, the raft may be launched to rescue porpoise or to clear fouled bunchlines. In sets where backdown is hampered or impossible, a rescuer, wearing a mask and snorkel, operating from a raft can be instrumental in reducing an otherwise certain high kill. Hand rescue efforts can make the difference between an above average kill and zero kill in many sets.

## ROLE OF THE CAPTAIN AND CREW

The successful execution of backdown and, for that matter, the entire purse seining operation, depends on the level of skill, motivation, and effort of the captain and crew. The captain has overall responsibility for initiating and directing the seining operations but cannot personally supervise each specific action by each member of his crew. Therefore, however broad or narrow responsibilities may be, each functioning member of the crew must 1) recognize circumstances requiring action, 2) know what action is required or to whom to report the circumstances, and 3) be able to execute the necessary action effectively. It is the captain's responsibility to ensure that his crew is competent and replace or train those who are not. The proper blend of skill and responsibility will inevitably lead to a highly competitive, self-motivated, and successful team.

The high rate of exchange of captains and crew among vessels detracts from the overall proficiency of execution of operations, and reduces the level of equipment maintenance. The operation and handling characteristics of each vessel and net combination necessitate a learning period. During this period, hitches in the operation, gear malfunctions, misinterpreted orders, etc. cause increased porpoise kill. Whenever a captain changes vessels, with or without changing crew, at least one trial set, with backdown, should be performed. By performing a trial set(s), the new captain may be able to identify specific vessel control characteristics for backdown, generally review crew performance, alter any aspects of the operation for greater efficiency, and have the chief engineer and deck boss identify any gear or machinery in need of attention.

Utilization of the information presented here will help lead to the lowest possible porpoise mortality rates achievable with the present state of purse seining technology. The maximum possible exchange of information, techniques, and ideas among the captains in the fleet is essential for the maintenance of low kill rates. The Expert Skipper's Panel (ESP), established through the American Tunaboat Association, is an excellent source of information for captains desiring to improve the efficiency of their fishing operations, especially on schools of porpoise. The ESP can help analyze the causes of problems in gear or procedures and make practical suggestions for their remedy.

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